MULTI-MODE WIRELESS CHARGING

BACKGROUND

[0001] Inductive wireless power transfer (IWPT) enables short range wireless power transfer from a power source to a load through inductive coupling. One application of inductive wireless power transfer is in the powering and charging portable consumer electronic devices, such as cell phones, smart phones, tablets, and laptop computers. In such an application, a portable device including an inductive coil is placed on a base station that also includes an inductive coil. The power source drives the inductive coil in the base station causing a transfer of electromagnetic energy from the power source inductive coil to the portable device inductive coil. The transferred energy is then used to power the portable device, e.g., to charge the batteries of portable device. Two IWPT techniques that are employed today in commercial products include tightly coupled inductive charging and loosely coupled charging.

[0002] A tightly coupled charging system works similar to a transformer and relies on a strong magnetic linkage, i.e., mutual inductance, between the source and load coils. To achieve the strong magnetic linkage, the load inductive coil may be placed in close proximity and in alignment with the power source inductive coil. Commercial examples of tightly couple charging systems include the Qi standard developed by the Wireless Power Consortium, and the Powermat™ standard adopted by the Power Matters Alliance (PMA).

[0003] In a loosely coupled charging system, efficient energy transfer is achieved through magnetic resonance of the load and source inductive coils rather than through strong magnetic linkage. Because loosely coupled charging systems do not rely on strong magnetic linkage between the coils, proximity and alignment of the coils is not as critical. A commercial example of a loosely coupled (or resonant) charging system is put forth in the Alliance for Wireless Power (A4WP) standard.

[0004] The different techniques (e.g., tight or loose coupling) may benefit from different design parameters to work efficiently. Such parameters that differ between the different techniques may include coil size, operating frequency, distance between coils, coil alignment, ferrite materials, shielding materials, etc. As such, a mobile device or appliance designed for one IWPT system may not work with a power source designed for a different IWPT system.

SUMMARY

[0005] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key or essential features of the invention.

[0006] Embodiments include, without limitation, an assembly including multiple inductive coils arranged concentrically for operating according multiple modes of inductive wireless power transfer. The assembly may include multiple layers of magnetic shields to protect device components from the effects of the magnetic field used for power transfer. Construction and materials of multiple layers of shields may be based on addressing individually the different operating parameters of the multiple modes of power transfer and/or based on the combined effect of the layers in each mode. One of the inductive coils may be tuned to operate in a tightly coupled inductive wireless power transfer configuration operating at a lower frequency and another one of the inductive coils may be tuned to operate at a higher frequency in a loosely coupled (or resonate) inductive wireless power transfer configuration. The tightly coupled coil may operate according to multiple different standards, and the loosely coupled coil may also operate according to multiple different standards.

[0007] Additional embodiments are disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Some embodiments are illustrated by way of example, and not by way of limitation, in the FIGS. of the accompanying drawings and in which like reference numerals refer to similar elements.

[0009] FIG. **1** illustrates multiple views of an inductive wireless power transfer assembly according to various embodiments.

[0010] FIGS. **2**A-B illustrate cross sectional views of example arrangements of a receiving coil assembly relative to a transmitting coil operated in multiple different modes according to various embodiments.

[0011] FIG. **3** illustrates an orthogonal view of example arrangements of a receiving coil assembly relative to a transmitting coil assembly operated in multiple different modes according to various embodiments.

[0012] FIG. **4** illustrates a cross sectional view of an example receiving coil assembly operated in one of multiple modes according to various embodiments.

[0013] FIGS. **5**A-**5**B illustrate cross sectional views of various receiving coil assemblies according to various embodiments.

[0014] FIG. **6** is a flow chart of an example method in accordance with various embodiments.

[0015] FIG. **7** shows an illustrative device in accordance with various embodiments.

DETAILED DESCRIPTION

[0016] In the following description of various embodiments, reference is made to the accompanying drawings, which form a part hereof, and in which various embodiments are shown by way of illustration. It is to be understood that there are other embodiments and that structural and functional modifications may be made. Embodiments of the present invention may take physical form in certain parts and steps, examples of which will be described in detail in the following description and illustrated in the accompanying drawings that form a part hereof.

[0017] FIG. **1** includes an illustrative example of a multi-coil assembly **100** for use in a portable device or charging base station to enable multiple modes of inductive wireless power transfer. FIG. **1** illustrates two views of the assembly, a top view and a cross-sectional view A-A'. As shown in the top view, assembly **100** includes inductive coils **101** and **104** arranged concentrically. Within the center of coil **101** a magnet **103** may be located. As shown in cross-sectional view A-A', coils **101** and **104** are oriented such that they may receive electrical power via electromagnetic flux from the base station side.

[0018] Assembly **100** may include multiple layers of magnetic shields, such as shields **102** and **105**. As shown in view A-A', magnetic shields **102** and **105** are oriented between a device side of the assembly and inductive coils **101** and **104**. In this example magnetic shield **105** extends the full area of